Available online at www.sciencedirect.com

ScienceDirect

Materials Today: Proceedings 5 (2018) 11845–11852

materialstoday: PROCEEDINGS

www.materialstoday.com/proceedings

ICMMM - 2017

Experimental Evaluation of the Effect of Refrigerant Charge and Capillary Tube Length on the Performance of Household Refrigerator with Different Configurations of R290 and R600a

D.V.Raghunatha Reddy [a*] P.Bhramara [b] K.Govindarajulu [c]

[a*] FST,IFHE University,Hyderabad, India
[b] JNTUH College of Engineering Hyderabad, India
[c] JNTU College of Engineering pulivendula, Andhra Pradesh, India

ABSTRACT:

In the present work the experimental investigation of a household refrigerator was calculated by simultaneously changing the refrigerant charge (mr) and length of capillary tube (Lc).The recent literature review shows the consistent research in the field of new refrigerants for usage in the refrigeration and air conditioning systems due to increased need and importance on the climate change effects faced by the humankind. The recent decades show the replacement of CFCs with HFCs, later with mixture of HFCs. But the high GWP value of HFCs paved the way for the development of new refrigerants using Hydro carbons or hydrocarbon mixtures. The present paper presents the experimental investigations on the domestic refrigerator using two different hydrocarbon mixtures, viz., R50/50(R290/R600a) and R436Awith mass fraction of 56/44of R290 and R600a. The experiments are conducted by changing the refrigerant charge (m_r) and length of capillary tube (L_C) at different evaporator temperature (T_e).Continuous consecutive lyand cycling tests are performed on the refrigerator under steady state situations. The pressure at the inlet and outlet of the compressor are note down and evaluated as well as the temperature readings can be observed at various positions in the refrigerator. And also the pull down time is noted for the three different refrigerants for varying refrigerant charge and length of capillary and graphs are plotted. The results show that the design temperature of -15^{0C}(according to IS1476 part1) and pull down time of 90 minutes are achieved by using 70g of R436A with L=4.5M,for CARE is achieved at pull-down time of 100minutes with 70g and L=5m and R134a achieved as 110minutes with 100g and 4m. The performance has shown that the R436A refrigerant can be the best substitute to R134a.

Selection and/or Peer-review under responsibility of International Conference on Materials Manufacturing and Modelling (ICMMM - 2017).

Key Words: *Hydrocarbon, Refrigerant mixture, Capillary tube length, Refrigerant charge and Alternative refrigerant.*

1. INTRODUCTION:

Refrigerator is main power consuming units in a domestic appliance [1].cloroflora carbons are the most important refrigerant gasin a household applications because it's have excellent thermal as well as physical properties. Then, it may be phased out quickly to permitting the Kyoto protocol due to its great global warming potential (GWP) of 1300 advanced than CO_2. Many researchers [2-4] ensure that GWP of hydro fluorocarbon (HFC) refrigerants are most important than that of chlorofluorocarbon (CFC) refrigerants. As regards the above problem a alternative refrigerants can be investigated. Due to high GWP of R134a the size of the system increases [5-7]. Various R134a refrigerant replacements that reach the requirements are a important method in this investigation. Various investigators have been described the mixed hydrocarbon refrigerants are originate to be an excellent eco-friendly alternative refrigerant option in a household refrigerator.

* Corresponding author. Tel.: +91-9948877134
*E-mail address:*raghunathadvrr@gmail.com

Selection and/or Peer-review under responsibility of International Conference on Materials Manufacturing and Modelling (ICMMM - 2017).

Nomenclature

GWP	Global Warming Potential
ODP	Ozone Depleting Potential
P	Pressure (bar)
T	Temperature (ºC)
mr	mass of Refrigerant (grams)
C_p	Specific heat of air (kJ/kgK)
ΔT_f	Temperature difference in Freezer compartment (ºC)
SLHE	suction line heat exchanger

Table- 1: Properties of refrigerants:

S.N0	Name of the Refrigerant	Critical pressure(MPa)	Critical temperature(K)	ODP (Yes/No)	GWP	ASHRAE flammability classification
1	R134a	4.06	374.21	NO	1300	A1
2	R290	4.25	369.89	NO	3	A3
3	R600a	3.63	407.81	NO	4	A3
4	R436A(R290/R600a)(54/46)	4.27	389.04	NO	3	A3

Fatouh M, ElKafafy M [8] Single hydrocarbon refrigerants are not accurate to substitute the R134a since the thermal properties and operating pressures are very high. Jung et al. [9] done using R290/R600a (60/40wt.) as substitute to R12 in a 299Las well as 465L domestic refrigerators also described that the energy efficiency and coefficient of performance (COP) and enhanced by 4 %&2.3. Akash and Said [10] experiments are conducted by LPG (60 % of R290 & 40 %R600a) as an alternate refrigerant to R12 in a household purpose at different weights like 50g, 80g and 100g. The results labeled from80 g of LPG refrigerant as confirmed the outstanding substitute in the direction of R12. Lee and Su.CC [11] presented an investigational effort on the vapor compression refrigeration system decided as isobutene (R600a) as the restored refrigerant than R12 & R134a.Because the COP of the system was improved. Wongwises and Chimres [12] examined by HCblends& HC/HFC refrigerants blends at various weight combinations are used in a 239Lof home appliances worked at surrounding temperature 298K to substitute for R134a. It concluded that the R290/R600 blend(60/40wt. %) is the ultimate alternative to R134a.Fatouh and Kafafy [13] tested using LPG as a substitute to R134a in a 280Lhousehold refrigerator worked at 316K surrounding temperature. The outcomes described the COP of the refrigerator LPG has improved by 7.6% than R134a.Sincethe lesser values of energy consumption by 10.8 %.The hypothetical study has resolved the capillary tube length for ternary hydrocarbon refrigerant combination(R290, R600&R600a) with 60 % R290 mass fraction requires 30 % increase in capillary tube length related to R134a.Since the presentation on house hold appliance system presented R134a reveals the lower performance when comparable by R290 at the identical operational situations. Firstly the system designed for R12 later it can be used for R290.Mani and Selladurai [14] were conducted the experiment on a vapor compression refrigeration system usingdifferentR290/R600a blends as an alternate refrigerants to R12 and R134a.The investigational significances presented that R290/R600a blend gives 28.6 to 38.2% greater refrigerating capacity than R134a.The R290/R600acombination is a zoetrope mixture which does not act a single constituent when it deviations its segment. The alliances do not remain constant, which indications to conformation by temperature limits [15]. Once the zoetrope's evaporates restricted the tubes, supplementary unstable element (R290) in the combination evaporates first and the liquid based refrigerant maintains a smaller amount of instable constituent (R600a). For the reason that of less unstable constituent (R600a) in liquid, the saturation temperature becomes reduced; as a moment the pressure drop is balanced[16].Based on above challenging issue the hydrocarbon combinations is to be present by chemically stable and nonreactive metallic constituents are used in compressor [17]. Subsequently the amount of hydrocarbon blends are in the system is equivalent or less than that of R134a, even if any leakages, happened in the hydrocarbon blends does not affect the system because it works with all ambient conditions and lower flammable limit.

The above proposals disclose that most of the investigators [4-17] ensure that the different hydrocarbon refrigerant combinations as substitute to R134a in a household appliances. Though, the possibility of using HCM as R436A (54% R290 & 46% R600a) is a substitute to R134a at various evaporating and different ambient temperature settings. The aim of the current experimental work is to search the probability of using above HCM in a 175Lhousehold refrigerator through different mass charges (mr) (60g,70g,80g,90g & 100g),evaporator temperature(Te) and different capillary tube lengths(Lc) are studied. The influence of the evaporator temperatures to optimize the performance of a refrigerator under constant and cycling consecutively working at different freezer temperatures with constant 29◦C ambient temperature have been conducted. In this study focused on the independent variation of refrigerant charge (mr) or capillary tube geometries (Lc), while study on the effect of simultaneous variation of these parameters is still lacking. Therefore, this extant to investigational thermodynamic performance to household refrigerator was experimentally studied by simultaneously varying (mr) and (Lc). The possibility of substituting to R134a by R436Ais present.

The primary objective of the experimental investigation is:

- In the direction ofto find the finest combination of Le and mr to give minimum pull-down time(to reach evaporator temperature is -15^{0}C.According to IS1476 Part1[20])

2. EXPERIMENTAL TEST RIG

Fig.1 shows a experimental setup of a single door household refrigerator work withR134a with the total capacity of 175L as shown in Fig. It consists of deep freezer, hermetically sealed reciprocating compressor air cooled condenser, strainer, and 5 capillary tubes with different length via ball valves. Initially the different length of capillary tubes are fixed after filter with the help of brazing method the specifications of for this tubes are maintained constant diameter(0.78 mm) and varying lengths (4m, 4.5m, 5m,5.5m & 6 m) can be used[13]. Domanski and Didion [18] concluded that the hydrocarbon refrigerant blends are given improvement of performance using advanced condenser (SLHE)to enhance the performance of a system. In this way to estimate the refrigerating effect, power consumption and coefficient of performance to household refrigerator. In this context a ball valves also fixed at the capillary inlet for operating with different combinations. The capillary outlet connected to evaporator then the refrigerant flows it(in the refrigerator cabin or calorimeter). The two Compound pressure gauges are connected with refrigerator at compressor inlet and outlet with precision is±0.25% to measure pressures. Seven thermocouple sensors are used for calibrate the(RTD Pt100) temperatures at inside the freezer, refrigerator cabin, evaporator, compressor and condenser inlets & outlets, the accuracy is ±0.25 K. During the experimentation the total experimental system is located in an open to atmosphere.

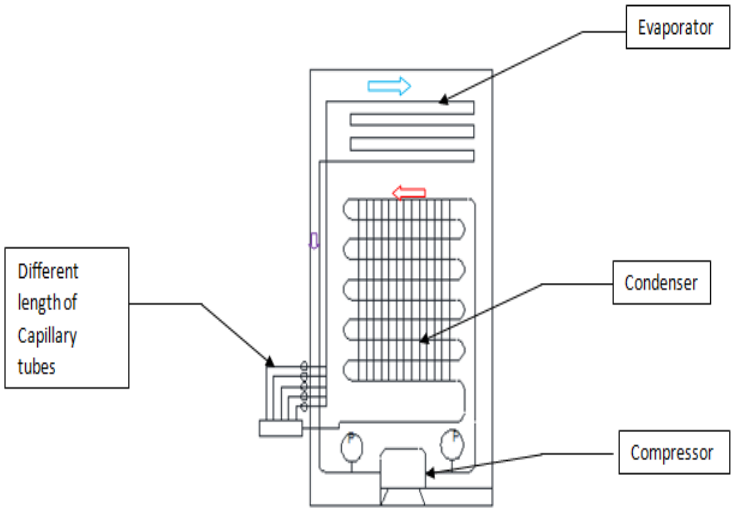

Figure:1. Schematic diagram of thetest rig.

2.1 Experimental procedure:

Initially the system was evacuated by vacuum pump up to-30psi pressure. After that hydrocarbon refrigerant mass 100 g of R600a/ R290 (56/44 by wt %) mixture used alternatively to the system. First we charged R600a/ R290 (56/44 by wt%) of 100 g mass in the system and calculate cooling capacity, compressor work and COP for different length (4,4.5,5.5,6m) and 0.036 inches diameter of capillary. Pull-down Test (PDT) on load carried out by connecting calorimeter in refrigerator. The experiments are performed based on ISO 8187 methodology[19]. First to perform pull down test for optimizing capillary length and mass of refrigerant at the door is kept open until the temperature of the refrigerator has to reach the steady state situation. As per design expert's suggestions R134a charge 100g of refrigerant was filled in the system for performing reference test. However throughout conducting tests with R134a, 4, 4.5, 5.5, &6m capillary tube length be used at different weights i.e. 60, 70, 80, 90&100grams. The continuous tests were carried out all through above conditions the evaporator temperature reached up to -15◦C. Initially the pull down characteristics can be determined and the performance parameters such as cooling capacity, power consumption and performance of the system. The outcomes can be carried out as per the methodology follows to the Sekhar and Lal [19]. For the period of testing, the ambient temperature be maintained around at 29 ◦C for changing capillary tube and varying weight of refrigerant. Total experimental values are collected after reaching the steady state circumstances. The performance tests to be carried out at different evaporator temperatures (−15,−12,−9,-6 and -3◦C). In this experimental analysis there is no need to change major modification in a household refrigerator. Therefore, in the experimental observations the possibility of HCM used polyesters as a lubricant oil. In this opinion the blended is with hydrocarbon refrigerants in the form of liquid state and this blends is calibrated with the help of electronic balancing machine, having a precision is ±0.01 g. In order to minimize the investigational work, to take average values to be measured. The dissimilarity in investigational values from the regular value be maintained within ±5% error. The observation values are recorded by every ten minutes. The experimental data are used to investigate the performance of a household appliances.

TABLE: 2. Pull down time (PDT) minutes for R134a at different Capillary tube length and Mass of Refrigerant

Mass of Refrigerant Charge (grams)	**Capillary Tube Length (meters)**				
	4	**4.5**	**5**	**5.5**	**6**
60	170	190	220	200	190
70	190	170	150	170	160
80	140	130	120	130	150
90	120	130	120	130	140
100	110	120	130	140	160

TABLE: 3.Pull down time (PDT) minutes for CARE at different Capillary tube length and Mass of Refrigerant

Mass of Refrigerant Charge (grams)	**Capillary Tube Length (meters)**				
	4	**4.5**	**5**	**5.5**	**6**
60	140	130	140	130	150
70	130	120	100	110	130
80	130	120	110	130	140
90	140	130	120	130	150
100	150	130	140	140	150

TABLE: 4. Pull down time (PDT) minutes for R436A at different Capillary tube length and Mass of Refrigerant

Mass of Refrigerant Charge (grams)	Capillary Tube Length (meters)				
	4	**4.5**	**5**	**5.5**	**6**
60	120	100	130	110	140
70	120	90	110	120	130
80	100	100	110	120	130
90	120	130	120	130	140
100	110	110	120	140	150

3. RESULTS AND DISCUSSION:

The effects of Lc and mr on the performance parameter Pull-down Temperature (PDT) were analyzed for R436A,CARE and R134a, with the objective of obtaining the best values of Lc and mr and to study the feasibility of using R436A in a VCRS designed for R134a. Fig.2,3 and 4 show the effect of Lc on the system with varying mass charge for all refrigerants..

3.1 Pull Down Characteristics: In this we reduce the temperature of from 29^0C (ambient temperature) to evaporator temperature (-15^0C) in continuous running test and it show that the design temperature of -15^{0C} (according to IS1476 part1) and it was observed that for different length of capillary and refrigerant charge in a pull down time of 90 minutes are achieved by using 70g of R436A R600a / R 290 mixture (54/46 by wt%) with L=4.5M,for , R290/R600a mixture (50/50 by wt%) CARE is achieved at pull-down time of 100minutes with 70g and L=5m and R134a achieved as 110minutes with 100g and 4m. It observed that cooling effect of mixture R436A was good as compound to R134a and the capillary length L=4.5M is suitable for the system. Fig. 4 show the variation of PDT to capillary length with respect to refrigerant charge for R134a and fig. 5&6 shows the variation of PDT to capillary length with respect to refrigerant charge for CARE and R 436A.

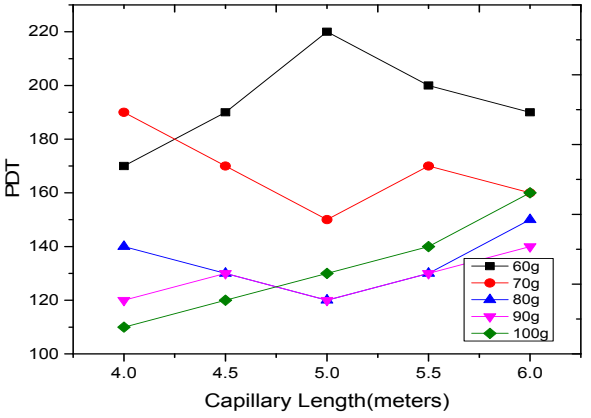

Fig.2 Pull down Time vs. capillary length of refrigerant R134a.

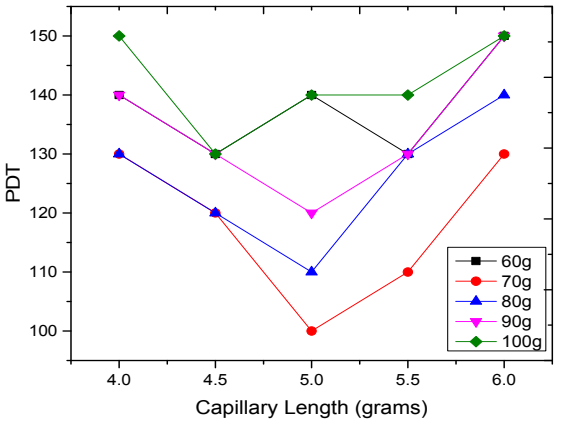

Fig.3 Pull down Time vs. capillary length of refrigerant CARE.

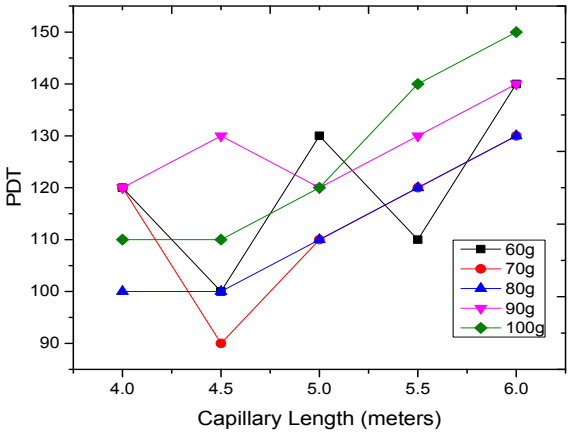

Fig.4 Pull down Time vs. capillary length of refrigerant R436A.

4. CONCLUSION

From the experimental investigation to optimize the capillary tube length and mass of refrigerant for CARE and R436A as an alternative to R134a in a single door household refrigerator. To considered input parameters like mass of refrigerant and capillary lengths of R134a, CARE and R436A.The investigation outcomes revealed to

- for all capillary length from 4 m to 6 m and mass of gas from 60g to 100g are used for all R134a, Hydro Carbon Mixtures (R600a/R290)such as CARE and R436A.The Evaporator temperature can be reached to -15^{o}C for reference test.
- All Experimental investigated values for CARE and R436A worked safely in the domestic refrigerator.
- Performance analysis on R134a refrigerant based VCR system with R134a, Hydro Carbon refrigerant mixture (R600a/R290) CARE and R436A was made the following conclusions

- The Pull down time of the R436A refrigerant was lesser than R134a for 4.5M length of capillary tube with 70g of refrigerant with desired evaporating temperature and CARE maintains in between R134a and R436A.i.e. 5M length of capillary tube with 70 g of refrigerant for all desired temperatures.
- Thus the results prove that the hydrocarbon refrigerant mixture R436A (R290/R600a) (54/46wt %) gives best performance than R134a in domestic refrigeration system.
- This mixture gives best result for replacement refrigerant in existing machines, designed for CFCs and HCFCs. i.e the capillary tube length 4.5M give good result than other higher length of capillary tubes.

Above conclusions confirm that the R436A is an suitable alternative to replace the R134a in all household refrigerators.

REFERENCES:

[1] R.Radermacher, K. Kim, Domestic refrigerators: recent developments.Int.J. Refrig. 19 (1996)61-69.

[2] Ashford P, Clodic D, McCulloch A, Kuijpers L. Emission from the foam and refrigeration sectors comparison with atmospheric concentrations, Part 2: results and discussion. Int J Refrig. 27 (2004)701–716.

[3] McCulloch A, Lindley AA. From mine to refrigeration: a life cycle inventory analysis of the production of HFC134a. Int J Refrig. 26 (2003) 865–872.

[4] McCulloch A, Midgley PM, Ashford P. Release of refrigerant gases (CFC12, HCFC22, HFC 134a) to the atmosphere. Atmospheric Environ. 37 (2003) 889–902.

[5] Li G, Hwang Y, Radermacher R. Review of cold storage materials for air conditioning application. Int J Refrig. 35 (2012)2053–2067

[6] Li G, Hwang Y, Radermacher R, Chun H-H. Review of cold storage materials for subzero applications. Energy. 2012. doi: 10.1016/j.energy.2012.12.0025 Available online 8 Jan 2013.

[7] Li G, Liu D, Xie Y. Study on thermal properties of TBAB-THF hydrate mixture for cold storage by DSC. J Therm Anal Calorim. 2010; 102(2):819–826.

[8] Fatouh M, ElKafafy M. Assessment of propane/commercial butane mixtures as possible alternatives to R134a in domestic refrigerators. Energy Convers Manag. 47 (2006) 2644–2658.

[9] Jung DS, Kim C-B, Song K, Park BJ. Testing of propane/isobutene mixture in domestic refrigerators. Int J Refrig. 23 (2000) 517–527.

[10] Akash BA Said SA. Assessment of LPG as a possible alternative toR-12 in domestic refrigerator. Energy Convers Manag. (2003); 44:381–388.

[11] Lee YS, Su CC. Experimental studies of isobutene (R600a) as the refrigerant indomestic refrigeration system. Appl Therm Eng. (2002); 22:507–519.

[12] Wongwises S, Chimres N. Experimental study of hydrocarbon mixtures to replace HFC134a in domestic refrigerators. Energy Convers Manag. 46 (2005) :85–100.

[13] Fatouh M, ElKafafy M. Experimental evaluation of a domestic refrigerator working with LPG. Appl Therm Eng. 26 (2006) 26: 1593–603.

[14] Mani K, Selladurai V. Experimental analysis of new refrigerant mixture asdrop-in replacement for CFC12 and HFC134a. Int J Therm Sci. 47 (2008):1490–5001.

[15] L. Rajapaksha, Influence of special attributes of zoetropic refrigerant mixtures on design and operation of vapor compression refrigeration and heat pump systems, Energy Conversion and Management 48 (2007) 539–545.

[16] K. Stephan, Two phase heat exchange for new refrigerants and their mixtures, Int. J. Refrig. 18 (1995) 198–209.

[17] D. Colbourne, T.J. Ritter, Compatibility of non-metallic materials with hydrocarbon refrigerants and lubricant mixtures, IIF–IIR Commission B1,B2, E1 and E2, Purdue University, USA, 2000.

[18] P.A. Domanski, D.A. Didion, Evaluation of suction-line/liquid-line heat exchange in the refrigeration cycle, Int. J. Refrig. 17 (1994) 487–493.

[19] ISO, International Standard Organization, International Standard-8187, Household refrigerating appliances (refrigerators/freezers) characteristics and test methods, International Organization for Standardization, Switzerland (1991).

[20] Performance of household refrigerating appliance-refrigerators with or without low temperature compartment-IS1476 (part1) :(2000).